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The R.A.I. limiter

TECHNOLOGICAL REPORT No. L-071

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RESEARCH DEPARTMENT

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for Head of Research Department

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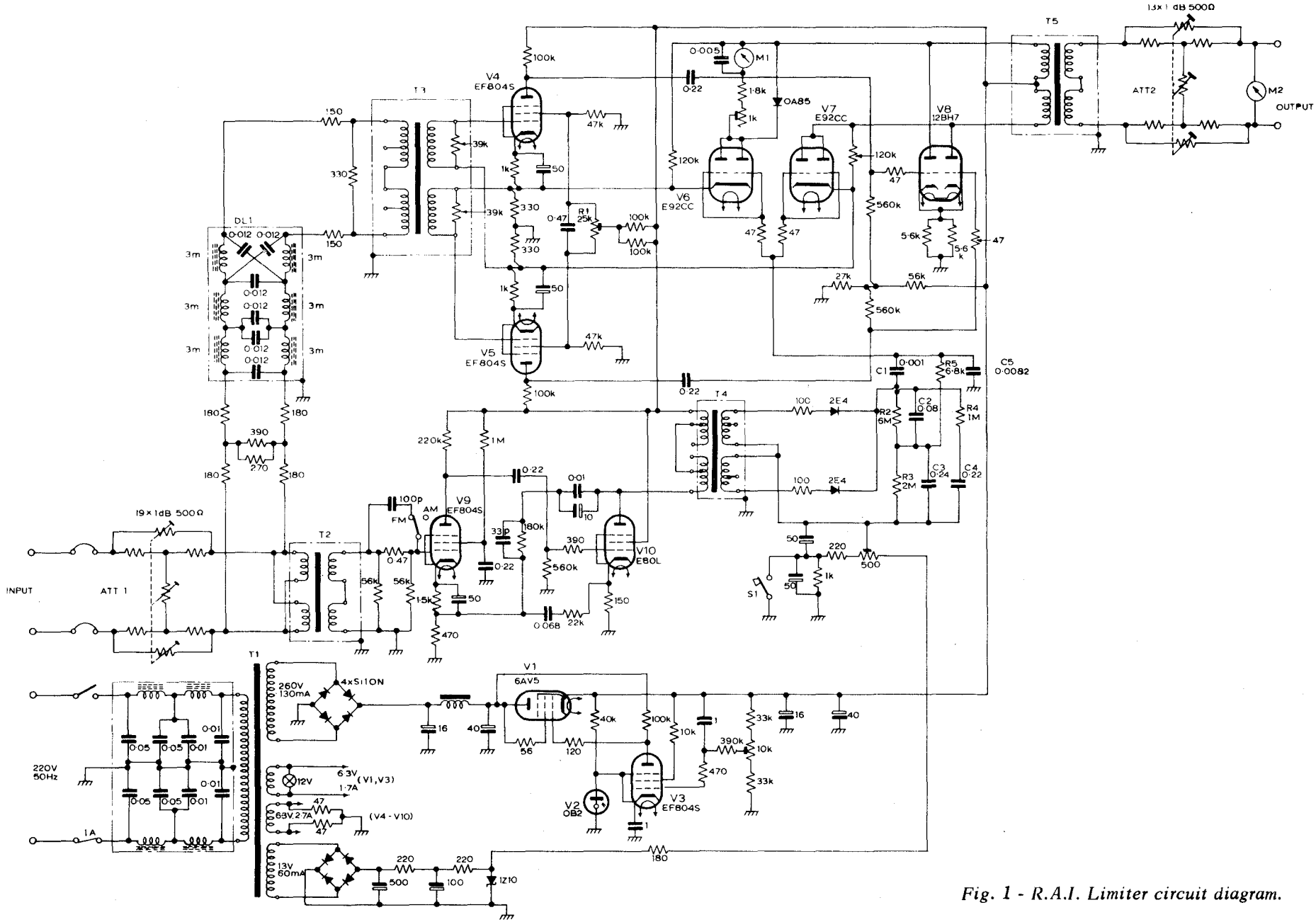

Fig. 1 - R.A.I. Limiter circuit diagram.

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SUMMARY

Tests have been carried out on a sound signal limiter designed by R.A.I. the Italian Radio and Television Service. In this device, a gain control system having an exceptionally short attack time, together with a signal delay network introduced ahead of the variable gain element, combine to reduce any transient overshoot of the output signal amplitude to very small proportions. Moreover, in an attempt to minimise the unaesthetic effects of limiting, the recovery time is arranged to increase automatically with the duration of the preceding gain reduction.

Unfortunately, the high rate of change of gain inherent in the operation of the system introduces severe distortion on a number of programme items and the device cannot therefore be recommended for use in high quality programme circuits.

1. INTRODUCTION

In the course of discussions in the European Broadcasting Union on the use of limiters for the protection of international sound programme circuits, the attention of the BBC was drawn to a device of this kind developed by R.A.I., the Italian Radio and Television Service, and a specimen was obtained for test. The R.A.I. limiter is designed to overcome the defect, common to most automatic level control devices, that the output signal amplitude under dynamic conditions can momentarily exceed the intended value because of the finite operating time of the gain regulating system. The desired end is achieved by an artifice which is well known but for instrumental reasons seldom applied; the control bias which regulates the gain is derived from the signal at the input of the limiter instead of at the output, while a delay network is introduced ahead of the variable-gain element so that the signal does not arrive at this point until the appropriate gain reduction has been carried out.

The choice of recovery time for a limiter involves a compromise between conflicting factors. In the case of a limiter used for purely protective purposes, and thus operating only occasionally, a short recovery time is desirable to avoid prolonged gain reduction after the occurrence of each excess signal; however, in the case of a limiter used to compress the dynamic range of the programme, and therefore operating frequently, a long recovery time is necessary to avoid deleterious effects such as "gain pumping". In the R.A.I. limiter the compromise solution adopted is that of a complex recovery characteristic, which gives a recovery time that increases with duration of gain reduction. A similar device was provided in early BBC limiters.

2. DESCRIPTION

Fig. 1 shows the circuit of the limiter. The input signal from a 500 ohm source, after passing in turn through a variable attenuator ATT1 and a 45 μs delay network DL1, is applied, through transformer T3, to a two-stage push-pull amplifier incorporating pentodes V4 and V5 followed by the double triode output stage V8; the output signal is taken from transformer T5 through a second variable attenuator ATT2 to the 500 ohm outgoing line. Negative feedback paths from the anodes of V8 to the cathodes of V4 and V5 are formed by the anode-cathode impedances of triodes V6 and V7 respectively. The impedance of these paths, and hence the gain of the amplifier, is controlled by bias applied to the grids of V6 and V7.

The signal input to the control chain is taken from the input to the delay network, through transformer T2, and amplified by pentodes V9, V10, whose gain is held constant by feedback networks; the control bias for V6 and V7 is derived by full-wave rectification and smoothing of the signal from transformer T4.

The network C1, C2, C3, C4, C5 and R2, R3, R4, R5 is arranged to give a recovery time increasing with the duration of the gain reduction. A

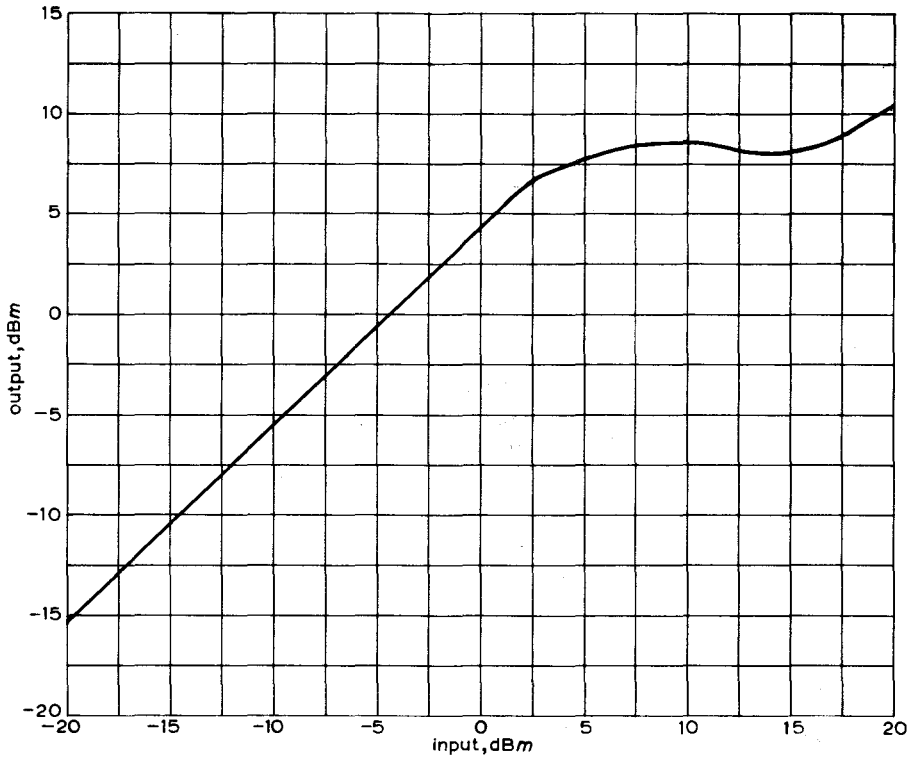


Fig. 2 - R.A.I. Limiter Output/Input Characteristic.

meter M1, indicating the anode current of V6, is calibrated in decibels of gain reduction. M2 is a standard V.U. meter connected across the output of the limiter. Balancing of the variable-gain system is effected by operating the push-button switch S1, which connects the control chain bias to earth and thus applies a positive-going pulse to the feedback valves V6 and V7; by adjustment of R1, the amplifier is then balanced for minimum output.

3. STATIC CHARACTERISTICS

3.1. Output/input characteristics

Fig. 2 shows the output/input characteristic. It will be seen that there is no sharp changeover from the linear to the limiting condition and that the nominally constant output region is restricted to some 12 dB; at higher input levels, the output can rise above the prescribed maximum. These features commonly occur in limiters deriving their control signal from the input, because of the difficulty of obtaining a variable-gain element with an appropriate gain bias law.

3.2. Frequency characteristic

The frequency characteristic was measured with an input of 0 dBm*, which is below the level at which limiting begins, and with 16 dBm input, giving 12 dB gain reduction; the resulting characteristic was in each case uniform within ± 0·2 dB relative to the level at 1 kHz from 20 Hz to 15 kHz. It should be noted that because of the automatic gain control action, the frequency characteristic measured in the limiting condition is an inverse function of the frequency characteristic of the control chain.

* dBm = decibels above one milliwatt.

3.3. Output and input impedances

The modulus of the output and input impedances were within 1% of the specified 500 Ω over the frequency range 20 Hz to 15 kHz.

3.4. Noise

The r.m.s. unweighted noise was -70 dB relative to the peak output of +8 dBm. The corresponding weighted noise figure, obtained with a network ASN/3 (C.C.I.F. 1949 Standard), was -81 dB.

3.5. Distortion

The r.m.s. total non-linear distortion of a 1 kHz tone at input levels of -8 dBm, +4 dBm and +16 dBm was in each case less than 0·1%.

4. DYNAMIC CHARACTERISTICS

4.1. Attack characteristic

The attack characteristic of a limiter is commonly specified in terms of the output signal envelope observed when a tone is suddenly applied to the input and maintained for an indefinite period.

However, when the limiter incorporates a delay network, this test can be misleading, for if the gain reduction is substantially complete by the time that the signal arrives at the variable-gain element, the form of the output envelope is independent of the time constants of the control system and thus yields no information on the response of the system to peaks of short duration.

For the present purpose, therefore, the standard test for attack characteristic was supplemented by an observation of the control bias voltage applied to the variable-gain system on the sudden application of tone to the limiter input. For a signal level such as to produce a steady-state gain reduction of 12 dB, the minimum time taken for the control bias to reach half of its final value was found to be of the order of only 10 μs; the limiter should therefore be capable of being operated by any peak likely to occur in an A.F. programme chain.

Figs. 3(a) and 3(b) illustrate the output waveform produced when signal levels of +16 dBm, at 10 kHz and at 1 kHz respectively, are suddenly applied to the input. The slight overshoot, about 2 dB in each case, shows the amount by which the gain at the end of the 45 μs delay period still exceeds the final steady-state value.

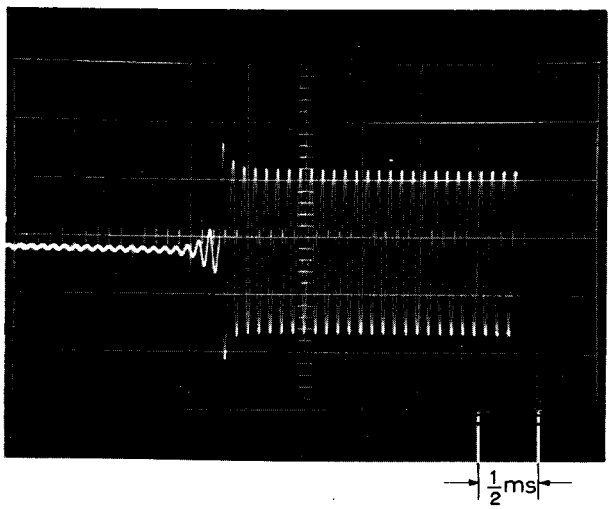
4.2. Recovery characteristic

The recovery characteristic was measured by applying, for a known period, an input signal at a level of +16 dBm (giving a gain reduction of 12 dB) and then switching in 20 dB of attenuation at the input. The recovery time is arbitrarily defined as the time then taken for the output signal level to return to within 4 dB* of its final value. As already indicated, the discharge circuit of the control bias rectifier is designed to give a recovery time which increases with the duration of the preceding gain reduction; the relationship between the two is shown in Fig. 4. It will be seen that the recovery time varies between 70 ms and 2·5 secs., these values corresponding respectively to 10 ms and over 3 secs. duration of the preceding gain reduction.

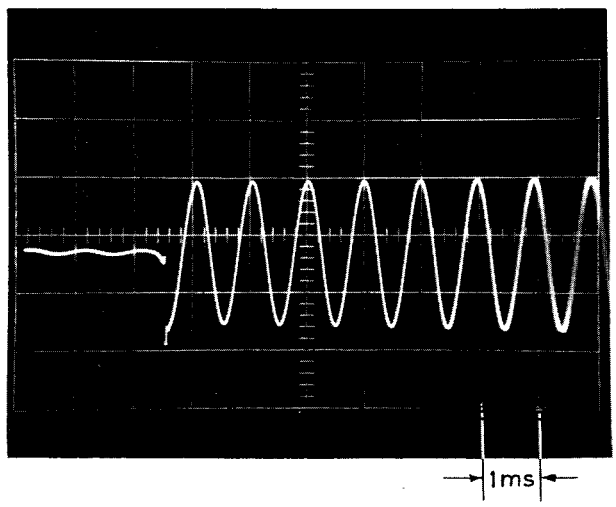
5. SUBJECTIVE TESTS

On listening tests, carried out with a variety of programme material, the limiter was found to introduce distortion in the form of short high-frequency pulses audible as clicks whenever the control circuit operated. The clicks were loud enough to be audible on speech, piano, orchestral and choral items, irrespective of the level of the incoming programme. The distortion was similar to that commonly encountered in quick-acting limiters when high-frequency components of the rectified signal in the control chain find their way - by accidental coupling or by unbalance in the variable-gain stage - into the programme output. In the case of the R.A.I. limiter, however, no audible effects attributable to this cause could be discovered, and the distortion heard must therefore be ascribed to the high rate of

* Following the principle of the C.C.I.T.T. specification for compressors, this level is chosen because on the linear scale of a C.R.O. it represents a point midway between the initial and final signal amplitudes, for a limiter having ideal static characteristics.



(a) 10 kHz



(b) 1 kHz

Fig. 3 - R.A.I. Limiter - Transient Response with suddenly applied +16 dBm signal

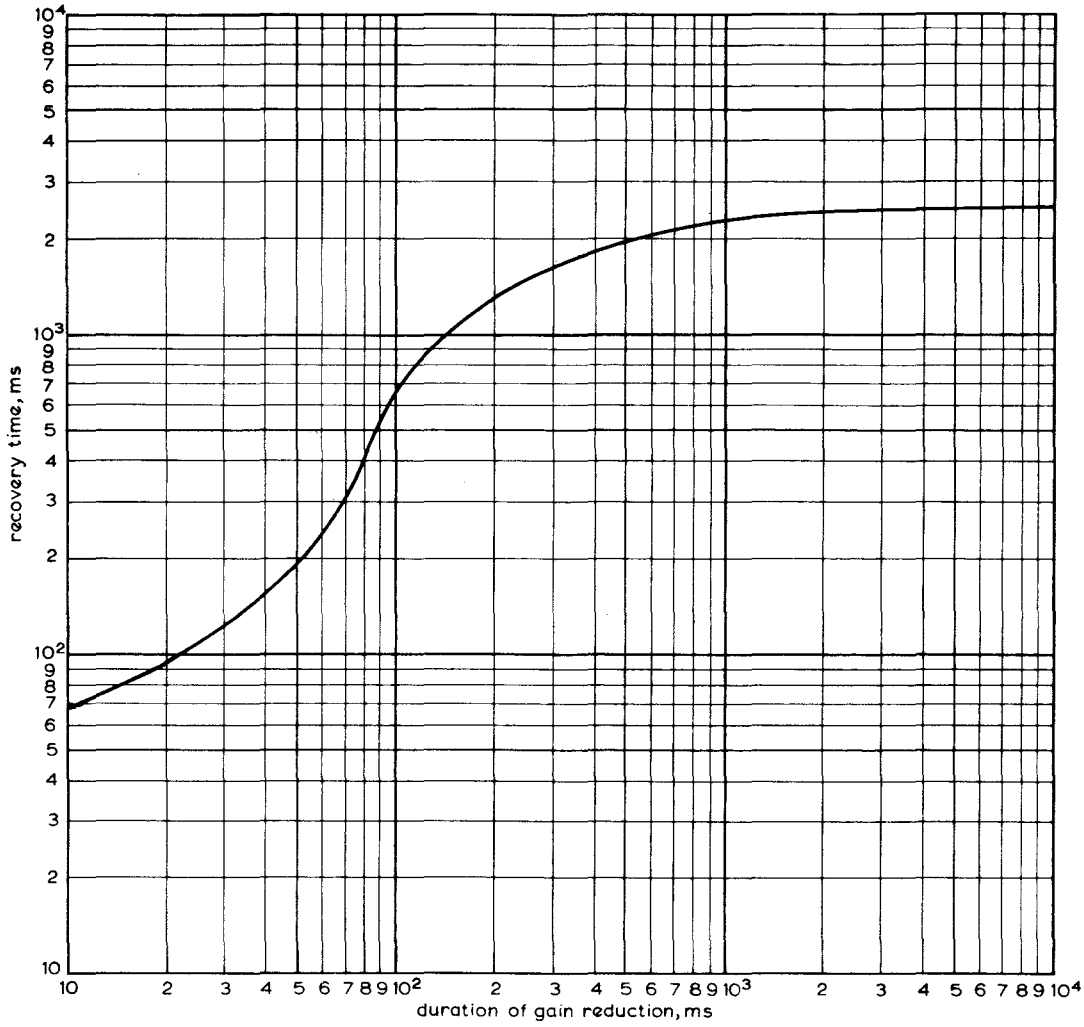


Fig. 4 - R.A.I. Limiter - Variation of Recovery Time with Duration of Gain Reduction.

change of gain* - exemplified by the initial transient in Fig. 3(b) - which occurs whenever the control system operates.

* This view is confirmed by other investigations - to be covered by a later report - into the dynamic performance of limiters in general.

6. CONCLUSIONS

In the R.A.I. limiter, the problem of avoiding momentary excursions of the signal above the prescribed maximum level has been largely solved. Unfortunately, the equipment introduces a degree of distortion which could not be tolerated in high quality sound transmission; this distortion is considered to be inherent in the rapid gain reduction effected by the control system.

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